

PERFORMANCE EVALUATION OF SOFTWARE COMPANIES USING DEA METHODS IN FUZZY ENVIRONMENT

G. ANUPAMA & V. V. S. KESAVA RAO

Part time PhD scholar, Department of Mechanical Engineering, College of Engineering (A),

Andhra University, Visakhapatnam, India

Professor, Department of Mechanical Engineering, College of Engineering (A),

Andhra University, Visakhapatnam, India

ABSTRACT

Data envelopment analysis (DEA) calculates the relative efficiency of homogenous decision- making units (DMUs) with multiple inputs and outputs. Classic DEA models usually suffer from several issues such as: discrimination power, variable weights of inputs/outputs, inaccurate efficiency estimation for small number of DMUs and incapability in working with zero and negative data. In this chapter, a four-phase DEA framework with initial relative weights on financial ratios is proposed to evaluate the financial performance of set of software companies in fuzzy environment. Data on the nine financial ratios is collected during FY2013-14 to FY2017-18. The crisp data on financial ratios is converted into triangular fuzzy numbers by utilizing the data during five financial years. The best relative efficiency of the ideal DMU and the worst relative efficiency of the nadir DMU are determined in fuzzy environment and combined to rank the DMUs. Performance evaluation of these companies is also made through hybrid GRA-DEA in fuzzy environment. Initial weights of the financial ratios are considered during evaluation of these companies in the proposed hybrid GRA-DEA method. The comparability of proposed approaches is made and final ranking of the companies is arrived.

KEYWORDS: Fuzzy Environment, Financial Ratios & GRA-DEA Method

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1. INTRODUCTION

The intensity of global competition and ever-increasing economic uncertainties has led organizations to search for more efficient and effective ways to manage their business operations. Measuring the performance of business processes has become a central issue in both academic and business, since organizations are challenged to achieve effective and efficient results. Applying performance measurement models to this purpose ensures alignment with a business strategy, which implies that the choice of performance indicators is organization-dependent. Nonetheless, such measurement models generally suffer from a lack of guidance regarding the performance indicators that exist and how they can be concretized in practice.

In this context, a suitable evaluation of the companies' performance is critical, not only for themselves but also for their own creditors and investors. The evaluation is one of the most important tools for identifying the internal strengths and weaknesses and determining the external opportunities and threats, and also can clarify the companies' position than other ones. Moreover, the evaluation based information can be used by future investors and creditors for selecting companies for the investment and lending to them, respectively. Despite the high importance of performance evaluation, a few numbers of the methods have been developed in this context, including some

conventional and simple methods. Here, the important issue in the evaluation is the development of mathematical approaches for ranking and the proposition of criteria.

In this study, the evaluation of software companies is implemented by multi-criteria decision-making (MCDM) methods. Because of the importance of the financial indicators for the investors and creditors, measurement of the companies' performance can be done by using financial ratios as the criteria are acquired from the balance sheet, income statement, and cash flow.

The model developed by Adel Hatami-Marbini et al. (2010) is extended by considering the relative weights for performance evaluation and ranking of software companies. Objective weight assessment methods like ENTROPY, CRITIC and ANN methods are used to determine common weights of financial ratios. Further, hybrid GRA-DEA method is implemented in fuzzy environment for evaluation of these companies.

In Section 2, literature review of financial performance measures and MCDM techniques focused on performance measures are given. In Section 3, four phased methodology is presented. In section 4, hybrid GRA-DEA method in Fuzzy environment is presented. In Section 5, application of the proposed methods for financial performance evaluation of 18 software companies listed in BSE is discussed. In section 6, the results of four phased DEA method and hybrid GRA-DEA method are compared. Results are summarised and suggestions for further research are outlined in section 7.

2. LITERATURE REVIEW

In recent years, data envelopment analysis (DEA) has been widely used to evaluate the financial performance of organizations. DEA is a mathematical programming approach that was originally developed by Charnes et al. (1978) and was extended by Banker et al. (1984) to include variable returns to scale. The basic DEA models are known as Charnes, Cooper and Rhodes (CCR) and Banker, Charnes, and Cooper (BCC).

Adel Hatami-Marbini et al. (2010) presented four phased DEA framework based on the theory of displaced ideal. In their study, two hypothetical DMUs called the ideal and nadir DMUs are constructed and used as reference points to evaluate a set of alternatives based on their Euclidean distance from these reference points. The best relative efficiency of the ideal DMU and the worst relative efficiency of nadir DMU are determined and combined to evaluate and rank the DMUs.

Kaveh Khalili-Damghani and Moslem Fadaei (2018) developed a comprehensive common weights data envelopment analysis model by considering Ideal and anti-ideal virtual decision making units to evaluate performance of decision making units.

A model for hybrid GRA-DEA was developed by Mohammad Sadegh Pakkar, (2016) in both pessimistic and optimistic point of view.

Negative inputs and outputs data are transformed using the relations presented by Ali and Seiford (1992) for effective implementation of DEA

Composite ranking is obtained through Copeland's Method (Masoomah Moghimi and Mohammadreza Taghizadeh Yazdi, 2013). This method calculates not only the number of superiority count, but also inferiority counts for each alternative. Difference between the superiority and inferiority value for each alternative is calculated. Alternatives are ranked based on the descending order of the difference value.

Chien-Ta Bruce Hoa and Desheng Dash Wu (2009) presented a hybrid approach to measure the performance of internet banking by using data envelopment analysis and principal components analysis (PCA).

Nese Yalçın Seçme et al. (2009) proposed a fuzzy multi-criteria decision model to evaluate the performances of banks. The largest five commercial banks of the Turkish banking sector are evaluated in terms of several financial and non-financial indicators.

Huafeng Xu and Shuke Zhou (2013) combined grey system theory and DEA to establish a grey DEA model to evaluate the performance of eight listed companies in Qingdao City, Shandong Province, China.

Bhattacharya and Chakraborty (2014) in his study evaluated the performance of eight IITs using a combined approach of DEA and TOPSIS.

Zeliha Kaygisiz Ertuğ and Nuray Girginer (2015) developed an evaluation model that considers the quantitative and qualitative criteria for the appropriate selection of firms demanding commercial credit for both public and private banks.

Mousa. G.A. (2015) examined the efficiency of business organizations in the Bahrain Bourse using financial ratio analysis (FRA) and DEA.

Asmita Chitnis and Omkarprasad S Vaidya (2016) proposed a unified approach based on DEA and TOPSIS to overcome the difficulty of unique ranking in the prevalent benchmarking and performance evaluation processes.

Mehdi Fallah Jelodar (2016) prioritized the factors affecting performance efficiency in the areas of management, personnel, finance, and customers using the methods of DEA and hierarchical analysis.

3. FUZZY FOUR PHASED DEA METHOD WITH RELATIVE WEIGHTS OF FACTORS

Adel Hatami-Marbini et al. (2010) presented four phased DEA framework, based on the theory of displaced ideal. In their study, two hypothetical DMUs called the ideal and nadir DMUs are constructed and used as reference points to evaluate a set of alternatives based on their Euclidean distance from these reference points. The best relative efficiency of the ideal DMU and the worst relative efficiency of nadir DMU are determined and combined to evaluate and rank the DMUs. The methodology is discussed below.

3.1 Four Phased DEA Methodology in Fuzzy Environment

Step-1: Obtain the data on the performance enablers.

In this, the input and output financial ratios are considered as performance enablers and the data on these financial ratios during various financial years need to be collected. The data on the financial ratios may be collected from secondary sources of data.

Step-2: Transform the data.

Many times, the data set will have negative numbers. Basic DEA models are not capable of completing an analysis with negative numbers, and all numbers must be non-negative and preferably strictly positive (no zero values). This has been defined as the “positivity” requirement of DEA. Negative inputs and outputs data is transformed using the relations presented by Ali and Seiford (1992).

Step-3: Obtain fuzzy data.

The data obtained from various financial years is converted into triangular fuzzy number to know expected possible performance of the alternatives. Let a , b and c be real numbers with $a < b < c$. Then the Triangular Fuzzy Number (TFN) $A = (a, b, c)$. In this study, minimum, average and maximum values of the enablers are considered for formulation of triangular fuzzy numbers.

Step-4: Obtain weighted fuzzy decision matrix.

In the proposed method, fuzzy data on the enablers is multiplied with crisp weights of the enablers.

Step-5: Obtain closeness coefficient of the alternatives (Software Companies).

Four phase methodology as discussed in section 3 is extended with weighted fuzzy decision matrix to obtain the best relative efficiency of the fuzzy ideal DMU, worst relative efficiency of the fuzzy nadir DMU, the best efficiency score of given DMU, the worst efficiency score of given DMU and relative closeness coefficient for given flexibility level.

Step-6: Ranking of alternatives.

The alternatives are ranked based on the relative closeness coefficient. Higher the closeness coefficients, better the alternative.

4. GRA-DEA METHOD

Data envelopment analysis, first proposed by Charnes, Cooper and Rhodes in 1978, based on the earlier work started by Farrell (1957) and developed by Banker (1984), is a mathematical technique developed in operations research and management science for measuring productive efficiency. The basic models of DEA are CCR (Charnes, Cooper, and Rhodes), BCC (Banker, Charnes and Cooper).

4.1 Proposed GRA-DEA Methodology in Fuzzy Environment

Step-1: Obtain the data on the performance enablers.

The data on the financial ratios may be collected from secondary sources of data.

Step-2: Transform the data.

Negative inputs and outputs data is transformed using the relations presented by Ali and Seiford (1992).

Step-3: Obtain Fuzzy data.

Data on performance enablers are transformed into triangular fuzzy number as discussed in step 3 of section 3.1.

Step-4: Obtain weighted fuzzy decision matrix.

Weighted fuzzy decision matrix is formulated as discussed in step 4 of section 3.1.

Step-5: Normalize the data on financial ratios.

It is difficult to compare between the different kinds of factors because they exert a different influence. Therefore, the standardized transformation of these factors must be done. Three formulas can be used for this purpose. Financial ratios of alternatives are normalized based on the normalization formula.

Calculate the normalized decision matrix R. Given $\tilde{X}_{ij} = (a_{ij}, b_{ij}, c_{ij})$ the normalized performance rating can be calculated as;

$$\tilde{r}_{ij} = \left(\frac{a_{ij}}{c_j^+}, \frac{b_{ij}}{c_j^+}, \frac{c_{ij}}{c_j^+} \right), \quad i = 1, \dots, m; j = 1, \dots, n \text{ for } J \in B$$

$$r_{ij} = \left(\frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}} \right), \quad i = 1, \dots, m; j = 1, \dots, n \text{ for } J \in C$$

where $c_j^+ = \max_i \{c_{ij}\}$ and $a_j^- = \min_i \{a_{ij}\} \forall i = 1, \dots, m$

Step-6: Determine absolute differences.

The absolute difference of the compared series and the referential series should be obtained by using the above equation.

Determine the reference series. The reference series can be defined as:

$$\tilde{R}_0 = [\tilde{r}_{01}, \tilde{r}_{02}, \dots, \tilde{r}_{0n}], \text{ where } \tilde{r}_{01} = \max(\tilde{r}_{ij}) \quad j = 1, \dots, n$$

Step-7: Find out maximum and minimum absolute differences.

The maximum and the minimum difference should be found from the absolute difference of the compared series and the referential series.

$$\tilde{\delta}_{ij} = |\tilde{r}_{0j} - \tilde{r}_{ij}|$$

Step-8: Determine Fuzzy grey relation coefficient

In fuzzy Grey relational analysis, Fuzzy Grey relational coefficient $\tilde{\xi}_{ij}$ can be expressed as shown in equation.

$$\tilde{\xi}_{ij} = \frac{\tilde{\delta}_{\min} + \zeta \tilde{\delta}_{\max}}{\tilde{\delta}_{ij} + \zeta \tilde{\delta}_{\max}} \quad \tilde{\delta}_{\max} = \max(\tilde{\delta}_{ij}), \quad \tilde{\delta}_{\min} = \min(\tilde{\delta}_{ij}) \text{ and resolving coefficient } \zeta \in [0, 1].$$

$$\alpha x_{ij}^M + (1 - \alpha) x_{ij}^L \leq \hat{x}_{ij} \leq \alpha x_{ij}^M + (1 - \alpha) x_{ij}^R, \quad \forall i, j$$

The distinguishing coefficient ρ is between 0 and 1. Generally, the distinguishing coefficient ρ is set to 0.5.

Step-9: Determine optimistic grey relation grade.

Optimistic grey relation grade is obtained by solving the dual model (Pakkar, 2016) as discussed below.

Step-10: Determine Pessimistic grey relation grade.

Pessimistic grey relation grade is obtained by solving the dual model as discussed by Pakkar, 2016.

Step-11: Determine normalized grey relation grade.

Normalized grey relation grade is obtained from the following relation as discussed by (Zhou et al., 2007).

Step-12: Determine ranking of alternatives: Alternatives are ranked based on the descending order of normalized grey relation grade.

5. CASE STUDY

Nine financial ratios of 18 software companies listed in BSC are considered in the case study. The original names of the companies are not disclosed.

6. RESULTS AND DISCUSSIONS

Performance Evaluation of Software Companies through Proposed Four Phased DEA Methodology in Fuzzy Environment

Data on financial Ratios

Nine financial ratios, as discussed in chapter 3 are considered as performance enablers for evaluation and ranking of eighteen software companies. Data on these financial ratios during FY 2013–14 to FY 2017–18 is presented in the below table 1.

Table 1: Average Values of Financial Ratios

Software Company	Stockholders Equity Ratio (FR1)	Turnover Rate of Accounts Receivables (FR2)	Turnover Rate of Inventory (FR3)	Return of stockholder Equity (FR4)	Quick Ratio (FR5)	Operating income Ratio (FR6)	Operating Cash Flow Ratio (FR7)	Return of Assets (FR8)	Market Share (FR9)
SWC1	0.4835	5.8657	1071.0390	-0.5958	0.4487	-0.0368	0.1244	-0.1191	0.0038
SWC2	0.0063	5.6527	153.4263	30.7891	2.3799	0.2270	0.6032	0.1867	0.1252
SWC3	0.0112	5.9329	3178.4408	19.5916	4.1768	0.2722	0.7303	0.1842	0.1935
SWC4	0.0159	4.5723	363.1890	6.6993	1.8083	0.1180	0.5084	0.1066	0.0101
SWC5	0.0170	6.6350	1284.0541	3.2239	2.5205	0.0753	0.3096	0.0499	0.0025
SWC6	0.0389	5.6359	1228.7885	5.2961	3.0064	0.1692	0.7537	0.1712	0.0138
SWC7	0.0287	8.0097	1813.4911	3.1501	3.4431	0.1563	0.5657	0.0898	0.0169
SWC8	0.0274	4.8101	3451.3026	3.7416	2.1626	0.1615	0.4399	0.1005	0.0084
SWC9	0.0065	5.6263	1542.9972	28.4322	4.3278	0.3908	0.6142	0.1832	0.0133
SWC10	0.0342	6.0779	1253.5642	4.2276	3.6714	0.1873	0.7130	0.1398	0.0074
SWC11	0.0177	2.6234	183.4787	0.9567	0.4572	0.3149	0.1419	0.0188	0.0103
SWC12	0.0315	5.5766	505.0253	5.8860	4.9653	0.0479	1.0348	0.1759	0.0015
SWC13	0.0113	6.4123	757.7908	13.7595	1.9409	0.0874	0.4018	0.1460	0.0063
SWC14	0.0023	5.0137	4190.0039	118.2106	3.9594	0.2773	1.0799	0.2648	0.3333
SWC15	0.0611	5.4071	3408.2780	4.0310	2.7842	0.2178	0.7857	0.2321	0.0033
SWC16	0.0179	5.2446	813.7534	8.0653	2.0701	0.1731	0.3880	0.1376	0.0807
SWC17	0.0085	5.4578	103.8384	15.6016	2.0906	0.2093	0.5367	0.1263	0.1606
SWC18	0.0236	6.0394	20.5325	5.6972	2.2980	0.1384	0.5424	0.1350	0.0090

Data transformation

Negative inputs and outputs data is transformed, using the relations presented by Ali and Seiford (1992).

Fuzzy data

In this study, minimum, average and maximum values of the enablers based on the five years data, triangular fuzzy numbers are formulated and presented in table 2.

Table 2: Fuzzy Data on Financial Ratios (Lower Value)

Software Company	Stockholders Equity Ratio (FR1)	Turnover Rate of Accounts Receivables (FR2)	Turnover Rate of Inventory (FR3)	Return of Stockholder Equity (FR4)	Quick Ratio (FR5)	Operating Income Ratio (FR6)	Operating Cash Flow Ratio (FR7)	Return of Assets (FR8)	Market Share (FR9)
SWC1	0.1298	4.7757	836.6929	0.0001	0.3774	0.0001	0.0001	0.0001	0.0027
SWC2	0.0047	4.3669	116.0055	21.4782	2.1518	0.9097	0.3787	0.4896	0.0989
SWC3	0.0050	5.5390	1301.0146	13.4082	3.4819	0.9631	0.5554	0.5182	0.1862
SWC4	0.0138	4.3579	73.0530	7.9184	1.5198	0.7973	0.2925	0.4397	0.0093
SWC5	0.0136	4.5697	1299.4242	2.8119	2.1025	0.7247	0.2468	0.3687	0.0016
SWC6	0.0199	5.4938	1299.7556	4.1088	2.3899	0.8305	0.5205	0.4698	0.0120
SWC7	0.0276	3.6304	1299.8089	3.0575	2.4361	0.8379	0.1757	0.3907	0.0103
SWC8	0.0228	4.0544	297.3188	3.4859	1.8866	0.8351	0.3187	0.4040	0.0079
SWC9	0.0043	5.2477	1299.1445	26.3843	1.8600	1.0700	0.4043	0.4872	0.0123
SWC10	0.0257	5.7189	1300.9625	5.0834	3.4367	0.8505	0.5549	0.4684	0.0066
SWC11	0.0145	1.9229	1297.3562	0.9776	0.3089	0.9849	0.0014	0.3382	0.0078
SWC12	0.0232	5.0058	146.0758	4.0358	3.9531	0.5513	0.2885	0.4508	0.0013
SWC13	0.0084	5.3559	201.6851	9.0097	1.6740	0.7596	0.2455	0.4654	0.0059
SWC14	0.0018	4.8818	3116.4230	99.4569	2.6936	0.9547	0.8651	0.5904	0.3244
SWC15	0.0432	5.0276	1301.3368	4.0291	1.8727	0.8733	0.5802	0.5386	0.0030
SWC16	0.0145	4.7352	410.4457	7.0869	1.9674	0.8396	0.2787	0.4553	0.0746
SWC17	0.0059	5.3047	79.0081	10.4619	1.9927	0.8866	0.5191	0.4501	0.1481
SWC18	0.0193	5.2878	16.9201	6.8516	1.9696	0.8134	0.3474	0.4513	0.0084

Table 3: Fuzzy Data on Financial Ratios (Middle Value)

Software Company	STOCKHOLDERS Equity Ratio (FR1)	Turnover Rate of Accounts Receivables (FR2)	Turnover Rate of Inventory (FR3)	Return of Stockholder Equity (FR4)	Quick Ratio (FR5)	Operating Income Ratio (FR6)	Operating Cash Flow Ratio (FR7)	Return of Assets (FR8)	Market Share (FR9)
SWC1	0.4835	5.8657	1071.0390	1.0213	0.4487	0.6592	0.1535	0.2283	0.0038
SWC2	0.0063	5.6527	153.4263	32.4062	2.3799	0.9231	0.6324	0.5342	0.1252
SWC3	0.0112	5.9329	1644.7311	21.2087	4.1768	0.9682	0.7594	0.5316	0.1935
SWC4	0.0159	4.5723	363.1890	8.3164	1.8083	0.8140	0.5375	0.4540	0.0101
SWC5	0.0170	6.6350	1299.9061	4.8410	2.5205	0.7713	0.3387	0.3974	0.0025
SWC6	0.0389	5.6359	1300.4664	6.9132	3.0064	0.8652	0.7829	0.5187	0.0138
SWC7	0.0287	8.0097	1788.0141	4.7672	3.4431	0.8523	0.5949	0.4372	0.0169
SWC8	0.0274	4.8101	3451.3026	5.3587	2.1626	0.8575	0.4690	0.4479	0.0084
SWC9	0.0065	5.6263	1301.9900	30.0493	4.3278	1.0868	0.6433	0.5306	0.0133
SWC10	0.0342	6.0779	1301.2332	5.8447	3.6714	0.8834	0.7422	0.4873	0.0074
SWC11	0.0177	2.6234	1297.5271	2.5738	0.4572	1.0109	0.1711	0.3662	0.0103
SWC12	0.0315	5.5766	499.4580	7.5031	4.9653	0.7439	1.0640	0.5233	0.0015
SWC13	0.0113	6.4123	751.458	15.3766	1.9409	0.7834	0.4309	0.4934	0.0063

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SWC14	0.0023	5.0137	4190.00 39	119.827 7	3.9594	0.9733	1.1091	0.6122	0.3333
SWC15	0.0432	5.0276	1301.33 68	4.0291	1.8727	0.8733	0.5802	0.5386	0.0030
SWC16	0.0179	5.2446	813.753 4	9.6824	2.0701	0.8691	0.4171	0.4850	0.0807
SWC17	0.0085	5.4578	103.838 4	17.2187	2.0906	0.9054	0.5659	0.4737	0.1606
SWC18	0.0236	6.0394	20.5325	7.3143	2.2980	0.8344	0.5716	0.4824	0.0090

Table 4: Fuzzy Data on Financial Ratios (Upper Value)

Software Company	Stockholders Equity ratio(FR1)	Turnover Rate of Accounts Receivables (FR2)	Turnover Rate of Inventory (FR3)	Return of stockholder Equity (FR4)	Quick Ratio (FR5)	Operating Income Ratio (FR6)	Operating Cash Flow Ratio (FR7)	Return of Assets (FR8)	Market Share (FR9)
SWC1	0.9961	6.9077	1689.2743	1.6971	0.5345	0.8532	0.3893	0.4052	0.0052
SWC2	0.0080	6.3151	201.6980	48.1136	2.4869	0.9460	0.7660	0.5641	0.1375
SWC3	0.0152	6.4964	3016.0000	38.8759	4.6421	0.9751	0.8798	0.5466	0.1988
SWC4	0.0172	4.7198	1350.6822	9.0938	2.0681	0.8362	0.7599	0.4753	0.0107
SWC5	0.0269	8.0919	1300.8451	7.5209	3.3349	0.8180	0.4941	0.4307	0.0037
SWC6	0.0506	5.7679	1301.4115	12.4277	3.8261	0.8972	0.9644	0.5622	0.0149
SWC7	0.0300	9.5450	2545.3073	5.9504	4.4497	0.8654	0.9415	0.4669	0.0202
SWC8	0.0331	5.6774	8298.0000	6.1732	2.7036	0.8715	0.6361	0.4731	0.0091
SWC9	0.0074	6.0902	1307.6618	33.9280	9.2470	1.0961	0.9421	0.5545	0.0148
SWC10	0.0444	6.3758	1301.5781	7.8491	3.9706	0.9442	0.8772	0.5088	0.0082
SWC11	0.0221	3.4431	1297.6936	3.3756	0.6016	1.0477	0.3170	0.3864	0.0128
SWC12	0.0427	6.4312	1303.9958	13.2588	6.0674	0.8341	1.8402	0.6709	0.0018
SWC13	0.0160	8.9554	1466.2900	20.1653	2.2570	0.7957	0.5740	0.5129	0.0067
SWC14	0.0029	5.1768	4862.4259	136.8318	5.1366	1.0035	1.4628	0.6329	0.3449
SWC15	0.0611	5.4071	3408.6518	5.6481	2.7842	0.9138	0.8149	0.5796	0.0033
SWC16	0.0242	6.2134	1405.6346	14.5884	2.2918	0.9185	0.5218	0.5374	0.0841
SWC17	0.0116	5.7028	121.6289	19.6456	2.2232	0.9179	0.6076	0.5074	0.1722
SWC18	0.0295	6.7336	25.0863	8.1049	2.6411	0.8494	0.7932	0.5073	0.0094

Weighted fuzzy decision matrix

The weights obtained from literature are considered to formulate weighted fuzzy decision matrix.

Ranking software Companies

Four phase methodology is implemented with weighted fuzzy data as discussed in section 4, and the software companies are ranked based on the relative closeness coefficient. Higher the closeness coefficients, better the alternative. Table-5 shows the ranking of the companies at different α values.

Table 5: Closeness Coefficients of SWCs at Possibility Level of 0.0

A = 0.0; $\theta^*1 = 69.464$; $\phi^*n = 2.65E-06$				
SWCs	Θ_p	Φ_p	CC	RANK
SWC1	1.64E-02	3.26E-06	8.79E-09	18
SWC2	1.00E+00	3.14E-04	4.54E-06	3
SWC3	2.94E-01	2.24E-04	3.19E-06	4
SWC4	9.65E-01	1.28E-04	1.82E-06	7
SWC5	5.67E-02	6.47E-05	8.94E-07	16
SWC6	9.31E-02	8.80E-05	1.23E-06	12

SWC7	4.41E-02	7.12E-05	9.88E-07	15
SWC8	1.85E-01	7.34E-05	1.02E-06	14
SWC9	2.58E-01	3.75E-04	5.38E-06	2
SWC10	5.79E-02	1.10E-04	1.55E-06	10
SWC11	2.54E-02	2.53E-05	3.27E-07	17
SWC12	7.32E-01	9.59E-05	1.36E-06	11
SWC13	9.36E-01	1.42E-04	2.04E-06	6
SWC14	4.35E-01	1.35E-03	1.95E-05	1
SWC15	4.10E-02	8.37E-05	1.17E-06	13
SWC16	3.35E-01	1.22E-04	1.73E-06	8
SWC17	1.00E+00	1.70E-04	2.44E-06	5
SWC18	1.00E+00	1.18E-04	1.69E-06	9

Similarly, closeness coefficients of SWCs at possibility levels at 0.5, 0.75 and 1.0 are determined and the companies are ranked.

Ranking of SWCs at different possibility levels using proposed four phased DEA model is shown in table-6.

Table-6: Ranking of SWCs at Different Possibility Levels

SWCs	$\alpha = 0.0$	$\alpha = 0.5$	$\alpha = 0.75$	$\alpha = 1.0$
SWC1	18	18	18	18
SWC2	3	3	2	3
SWC3	4	4	4	5
SWC4	7	8	9	7
SWC5	16	16	15	16
SWC6	12	12	11	11
SWC7	15	13	13	17
SWC8	14	14	14	15
SWC9	2	2	3	2
SWC10	10	11	12	13
SWC11	17	17	17	4
SWC12	11	9	8	14
SWC13	6	6	6	10
SWC14	1	1	1	1
SWC15	13	15	16	9
SWC16	8	7	7	8
SWC17	5	5	5	6
SWC18	9	10	10	12

From the table 6, it is observed that possibilistic performance ranking of SWC14 (Rank = 1) and SWC1 (Rank = 18) are same at all possibilistic levels. Analysis of variance is conducted to know the significance of possibility level and the results are presented in table 7.

Final ranking obtained by taking the average ranks obtained with different possibility level. Final ranking of SWCs using proposed four phase method with initial weights of financial ratios is presented below.

Table 7: Average Ranking of SWCs Through Proposed Four Phase DEA Method

SWCs	Average Rank	SWCs	Average Rank
SWC1	18	SWC10	12
SWC2	3	SWC11	14
SWC3	4	SWC12	10
SWC4	8	SWC13	6
SWC5	17	SWC14	1
SWC6	11	SWC15	13
SWC7	16	SWC16	7

SWC8	15	SWC17	5
SWC9	2	SWC18	9

From table 7, it is observed that highest performance is obtained for SWC14 and the lowest performance is obtained with SWC1.

7. PERFORMANCE EVALUATION OF COMPANIES THROUGH PROPOSED GRA-DEA IN FUZZY ENVIRONMENT

The 18 software companies are evaluated through proposed hybrid GRA-DEA in Fuzzy environment, as discussed in section 4 and 3.

Ranking of SWCs

Optimistic grey relation grade is obtained by solving the dual model (Pakkar, 2016) using the fuzzy grey relation coefficients. The model proposed is coded in lingo and solved using lingo solver 8.0 and optimistic, pessimistic grey relation grades are obtained at different possibilistic levels ($\alpha=0.0, 0.5, 0.75$ and 1.0). Then, normalized grey relation grades of SWCs are determined and are ranked for each possibility level based on normalized grey relation grades values.

Table 8: Ranking of SWC using Proposed Fuzzy GRA-DEA at $\alpha = 0.0$

SWCs	Γ	Γ'	B	Rank
SWC1	0.5237	1.0000	0.1837	4
SWC2	0.4733	1.0000	0.0986	9
SWC3	0.5114	1.0346	0.2596	2
SWC4	0.4194	1.0000	0.0076	17
SWC5	0.4376	1.0000	0.0383	15
SWC6	0.4499	1.0000	0.0592	12
SWC7	0.4849	1.0000	0.1183	8
SWC8	0.5051	1.0000	0.1524	6
SWC9	0.5212	1.0141	0.2189	3
SWC10	0.4486	1.0000	0.0571	13
SWC11	0.4149	1.0000	0.0000	18
SWC12	0.5170	1.0000	0.1724	5
SWC13	0.4553	1.0000	0.0683	11
SWC14	0.7110	1.1793	1.0000	1
SWC15	0.4526	1.0293	0.1454	7
SWC16	0.4478	1.0000	0.0556	14
SWC17	0.4571	1.0000	0.0713	10
SWC18	0.4322	1.0000	0.0292	16

Similarly, normalised grey relation coefficients for 18 software companies at different α (alpha) levels are determined, and these companies are ranked based on normalised grey relation coefficients.

Ranking of SWCs at different possibility levels using proposed Fuzzy GRA-DEA model is determined and shown in table 9.

Table 9: Ranking of SWCs at Different Possibility Levels

SWCs	+Possibility Level			
	$\alpha = 0.00$	$\alpha = 0.50$	$\alpha = 0.75$	$\alpha = 1.00$
SWC1	4	8	13	16
SWC2	9	4	4	4
SWC3	2	2	2	2
SWC4	17	17	17	17

SWC5	15	15	16	15
SWC6	12	11	9	9
SWC7	8	7	6	6
SWC8	6	9	10	11
SWC9	3	3	3	3
SWC10	13	10	8	8
SWC11	18	18	18	18
SWC12	5	6	7	7
SWC13	11	14	14	13
SWC14	1	1	1	1
SWC15	7	12	12	12
SWC16	14	13	11	10
SWC17	10	5	5	5
SWC18	16	16	15	14

From the table-9, it is observed that possibilistic performance ranking of SWC14 (Rank = 1), SWC3 (Rank = 2), SWC9 (Rank = 3), SWC4 (Rank = 17) and SWC11 (Rank = 18) are same at all possibilistic levels.

Final ranking obtained by taking the average ranks obtained with different possibility level. Final ranking of SWCs using proposed fuzzy GRA-DEA method with initial weights on financial ratios is presented below.

Table 10: Average Ranking of SWCs through Proposed Fuzzy GRA-DEA Method

SWCs	Average Rank	SWCs	Average Rank
SWC1	11	SWC10	9
SWC2	4	SWC11	18
SWC3	2	SWC12	5
SWC4	17	SWC13	14
SWC5	15	SWC14	1
SWC6	10	SWC15	12
SWC7	7	SWC16	13
SWC8	8	SWC17	6
SWC9	3	SWC18	16

From table 10, it is observed that highest performance is obtained for SWC14 and the lowest performance is obtained with SWC11.

Composite Ranking of SWCs

Copeland's Method as discussed by Masoomah Moghimi and Mohammad reza Taghizadeh Yazdi(2013)is extended for arriving composite ranking from the rank values obtained by proposed fuzzy four phased DEA method and Fuzzy GRA-DEA methods.

Comparison of Ranks: Average Ranks obtained *through* fuzzy four phased DEA method and Fuzzy GRA-DEA methods are presented in table 11.

Table 11: Comparison of Ranks

SWCs	Fuzzy Four Phase DEA Method	Fuzzy GRA-DEA Method
SWC1	18	15
SWC2	3	4
SWC3	4	3
SWC4	8	13
SWC5	17	17
SWC6	11	9

SWC7	16	11
SWC8	15	12
SWC9	2	2
SWC10	12	10
SWC11	14	18
SWC12	10	6
SWC13	6	7
SWC14	1	1
SWC15	13	14
SWC16	7	8
SWC17	5	5
SWC18	9	16

Correlation between the proposed two methods is determined using Minitab 17.0. From the correlations between ranking methods, it is observed that there is high significant positive correlation of 0.833 (0.000) existed between the proposed methods. The p-values for the individual hypothesis tests of the correlations are being shown in brackets. Since the p-values are less than or equal to 0.05, there is sufficient evidence at $\alpha = 0.05$ that, there exists significant correlation between the two ranking methods.

Composite Ranking: Composite ranking is obtained through Copeland's Method (Masoomah Moghimi and Mohammadreza Taghizadeh Yazdi, 2013). This method calculates not only the number of superiority count, but also inferiority counts for each alternative. Difference between the superiority and inferiority value for each alternative is calculated. Alternatives are ranked based on the descending order of the difference value. The table-12 shows the difference values of the alternatives.

Table 12: Composite Rank

SWCs	Superiority Count	Inferiority Count	Difference	Composite Rank
SWC1	3	14	-11	15
SWC2	14	3	11	4
SWC3	15	2	13	3
SWC4	5	12	-7	13
SWC5	1	16	-15	17
SWC6	9	8	1	9
SWC7	7	10	-3	11
SWC8	6	11	-5	12
SWC9	16	1	15	2
SWC10	7	9	-2	10
SWC11	0	17	-17	18
SWC12	12	5	7	6
SWC13	11	6	5	7
SWC14	17	0	17	1
SWC15	4	14	-10	14
SWC16	10	7	3	8
SWC17	13	4	9	5
SWC18	2	15	-13	16

From the table 12, it is observed that the final ranking is: SWC14>SWC9>SWC3>SWC2>SWC17>SWC12>SWC13>SWC16>SWC6>SWC10>SWC7>SWC8>SWC4>SWC15>SWC1>SWC18>SWC5>SWC11. SWC14 is showing the best performance followed by SWC9. SWC11 is showing the poor performance.

8. CONCLUSIONS

In this thesis, the study proposed two methods: Fuzzy Four phased DEA method and Fuzzy hybrid GRA-DEA with initial relative weights of financial ratios for evaluation ranking of eighteen software companies, listed in BSE. Relative weights obtained through objective methods are considered in the study. The rankings arrived by using different approaches are similar and there is a high correlation among the ranking methods, though each ranking model has its own objective function. In general, in order to select the most appropriate model, the user (decision maker) has to set the criterion (objective function) that is most suitable for his/ her purpose (or to his/her opinion), and then decide on the approach to be used. Also, it is suggested to use the composite rankings in arriving final ranking of banks. In this study, composite ranking of software companies is arrived through Copeland's method by aggregating the proposed two methods. These results have provided useful information indicating how relatively the software companies are performing in financial perspective and make a basis for changing or improving their business activities in the future time.

DEA methods and its variants seem to be a useful tool for the multi-criteria analysis and the ranking of alternatives. The advantage of the proposed methods consists in the fact that, the weights of the indicators (inputs and outputs) are not estimated subjectively. In this research, eighteen software companies listed in BSE is considered and accordingly implemented the proposed research methodologies to give out meaningful and helpful results to the development of the industry. This study could be extended for financial performance analysis of variety of industries.

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AUTHORS PROFILE



G. Anupama has started her career in a Diploma institute as a lecturer and worked there for a year. After that she worked as a design engineer in L&T Ltd. Company for almost 2 years. While working, she pursued her Masters in Industrial Engineering from Andhra University. She restarted her teaching career in 2011 as an Assistant professor in Sankethika Engineering College and subsequently worked in various engineering colleges. She has been promoted to Associate professor in WELFARE Engineering College in 2017 and since then she is working in the same position. She is pursuing her Phd in Andhra University as part time research scholar since 2014.



Prof V.V.S. Kesava Rao has started his career in the year 1986 as maintenance engineer in SAIL and then shifted to Visakhapatnam steel plant there he worked as maintenance engineer from 1988 to 1993. He started his career as lecturer in GITAM Visakhapatnam and worked there for 9 months and then appointed as lecturer in 1994 in Department of Mechanical engineering, College of Engineering (A) Andhra university Visakhapatnam. From 1994 onwards he continuously working in Andhra university and was promoted as Associate Professor in 2003 and as Professor in 2006. From 2006 onwards he is working in Andhra university only. He guided so far 17 Phds, 90 M.Tech projects and produced 78 papers in National and international journals.